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- Lorentzen (G.) Ueber die Untersuchung der Scalen eines Helio-
meters. 4to. *Kiel* 1892. The Author.
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Glykogens. 8vo. *Bonn* 1893. The Author.
- Volger (G. H. O.) Die Lichtstrahlen. 8vo. *Emden* 1892.
The Author.
- Wilson (W. E.) and A. A. Rambaut. The Absorption of Heat in
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February 9, 1893.

Sir JOHN EVANS, K.C.B., D.C.L., LL.D., Vice-President and
Treasurer, in the Chair.

A List of the Presents received was laid on the table, and thanks
ordered for them.

The following Papers were read :—

- I. "Preliminary Account of the Arrangement of the Sympa-
thetic Nervous System, based chiefly on Observations
upon Pilo-motor Nerves." By J. N. LANGLEY, F.R.S.,
Fellow of Trinity College, Cambridge. Received January
21, 1893.

[PLATE 14.]

I propose to give here a general statement of some of the conclu-
sions which I have come to with regard to the arrangement of the
sympathetic nervous system, reserving detailed treatment for a later
time. As a starting point I take the distribution of the pilo-motor
nerves in the cat.*

In the cat, the spinal nerves which contain pilo-motor fibres in their
nerve-roots, are usually the 4th thoracic to the 3rd lumbar inclusive.
Such fibres are, in rare cases, present in the 3rd thoracic nerve, and
occasionally in the 4th lumbar nerve.

* A certain number of facts with regard to this, I have given in an earlier paper
written in conjunction with Dr. Sherrington. Dr. Sherrington dealt with the
pilo-motor nerves in the monkey (*cf.* 'Journ. of Physiol.,' vol. 12, p. 278, 1891).

The spinal pilo-motor fibres run into the sympathetic trunk, there they become connected with nerve-cells; on leaving the sympathetic chain, they run to their peripheral endings in cranial or spinal nerves. The fibres to the body accompany those dorsal cutaneous branches of the spinal nerves which supply the skin over and close to the vertebræ.

Broadly speaking, the pilo-motor fibres run from the sympathetic chain to the cranial and spinal nerves in the grey rami, but a few fibres may run out in the white rami; and in some of the upper thoracic rami, as is well known, no anatomically separable white rami occur.

Broadly speaking, the fibres issuing from any one ganglion are connected with nerve-cells in that ganglion, and with no other sympathetic nerve-cell. In some cases a certain number of such fibres are connected with nerve-cells, not in the ganglion from which they issue, but in the ganglion immediately above or below it. In the following statement these fibres, and those which may take the course of the white rami, are, for the sake of simplicity, left out of account.

The fibres, before and after they have joined nerve-cells, I shall call respectively pre-ganglionic or pre-cellular, and post-ganglionic or post-cellular.

Each ganglion, by its post-ganglionic fibres, supplies, in any one individual, a definite portion of skin. This portion varies somewhat in different individuals. The more important variations only will be mentioned here.

The areas supplied by the ganglia from above downwards, starting with the superior cervical ganglion, are, apart from a variable amount of overlapping, successive areas.

An overlapping of the areas occurs when one nerve receives post-ganglionic fibres by more than one ramus; thus the 3rd cervical nerve, and so the skin of the upper part of the neck, may receive pilo-motor fibres from the superior cervical ganglion by one grey ramus, and from the ganglion stellatum by another grey ramus; not uncommonly the 7th lumbar nerve, and so the skin over the upper coccygeal vertebræ, receives pilo-motor fibres by two separate grey rami, one from the 7th lumbar ganglion, and the other from the 1st sacral ganglion. Similarly, also, a lower thoracic, or upper lumbar, nerve may receive pilo-motor fibres by the grey ramus of its own ganglion, and others by the white ramus which it gives off to the ganglion below.

A second cause of overlapping is a spreading out of the pilo-motor fibres in the skin itself. When two successive grey rami, or two successive dorsal cutaneous branches, are stimulated one after the other, the area of skin affected by both of them may be not more than $\frac{1}{2}$ to 1 mm.; but it may be about 5 mm., and in such case the

“exclusive” area of a ramus may be about a half only of the total area supplied by it.

A third cause of over-lapping may be the formation of a plexus in the dorsal cutaneous branches of the spinal nerves; this is, perhaps, the cause of some of the cases of over-lapping of areas which I have observed in the sacral and coccygeal regions.

Most of the details with regard to the over-lapping of the areas we may leave on one side, and, treating the areas as successive, proceed to consider their position.

The cranial rami of the superior cervical ganglion supply the skin of the dorsal part of the head, except a posterior portion, beginning about $1\frac{1}{2}$ cm. behind the anterior level of the ears; this unaffected region we may call the occipital region.

The cervical rami of the superior cervical ganglion supply the skin of the occipital region of the head by fibres running in the great occipital (2nd cervical) nerve, and the skin over the first three or four cervical vertebræ by fibres running in the 3rd cervical nerve.

The ganglion stellatum, by its cervical rami, supplies the skin from the 3rd and 4th cervical vertebræ to some point between the spine of the 2nd and 3rd thoracic vertebræ. Often its area extends upwards to join the occipital region.

The areas supplied by the post-ganglionic pilo-motor fibres of the 3rd 4th, 5th, and 6th cervical nerves vary in relative size in different individuals; roughly, we may take the 3rd nerve as supplying the skin over the first three and a half vertebræ, and the others as supplying successive strips of about two vertebræ each.

We come now to the fore leg region, in which one, two, or three spinal nerves send no cutaneous branches to the mid-line of the back. These are the 7th and 8th cervical, and the 1st thoracic, nerves.

Sometimes the 7th, sometimes the 1st, thoracic has such a cutaneous branch; when it is present it contains pilo-motor nerves. I have not, in any case, observed any such cutaneous branch from the 8th cervical nerve. Corresponding to the presence or absence of these cutaneous branches—so far as my experiments go—is the presence or absence of pilo-motor fibres in the rami which pass from the ganglion stellatum to the respective nerves. Thus, if the 1st thoracic nerve sends a branch to the skin over the vertebræ, stimulation of its ramus, as of the branch itself, causes a movement of hairs.

In the two experiments in which there was a mid-line cutaneous branch from the 7th cervical nerve, it supplied the lower part of the area usually supplied by the 6th nerve, the area of this and of the 5th and 4th nerves lying a little more anteriorly than usual.

The ganglion stellatum also sends pilo-motor fibres to the first four thoracic nerves. From the 5th thoracic nerve downwards (and sometimes from the 4th) there is a ganglion and ramus for each nerve.

The distribution of all these rami down to the 4th lumbar we may consider together.

The area of the 2nd thoracic ramus (or of the 1st, as mentioned above) follows on the area of the lowest effective cervical ramus. The 4th lumbar ramus supplies either the skin over the 7th lumbar vertebra and a small piece of sacrum, or the skin over the sacrum. Between the limits just given for the 2nd thoracic and the 4th lumbar the areas follow on each other, the length of each area being about that of a vertebra. There are variations in the relative length of the areas in different animals, but, generally speaking, we may say that in the thoracic region the areas are a little larger than the neighbouring vertebræ, and in the upper lumbar region a little shorter.

Below the 4th lumbar nerve we reach the hind leg region, which is like that of the fore leg already mentioned, in so far as one, two, or three nerves have no dorsal cutaneous branches to the mid-line, and the corresponding rami have no pilo-motor fibres. These nerves are the 5th, 6th, and 7th lumbar. On the rami of these nerves I have made many more experiments than on the rami of the ganglion stellatum, and, no doubt in consequence, I have found greater variation. Thus, as I have said, I have not so far observed any case in which the ramus to the 8th cervical nerve contained pilo-motor fibres. In the lumbar region the 6th nerve is that which most frequently has no pilo-motor fibres, but in two cases it apparently did contain some; it is worth mention that in these cases the lumbo-sacral plexus was an extreme form of my Class I* (posterior type of arrangement, part of Sherrington's† post-fixed plexus), the 7th nerve sending a filament to the obturator. The 5th lumbar ramus has pilo-motor fibres more commonly than the 7th.

About the end of the sacrum appears to be the dividing line between the areas of the rami which come from above and those which come from below the ineffective ramus or rami. Thus the skin over the lower part of the sacrum may be supplied by the 4th, 5th, or, perhaps, the 6th lumbar ramus, the skin over the upper coccygeal vertebræ by the 7th lumbar or 1st sacral. In each case there are one or more nerves, lying between the nerve which supplies the lower part of the sacral region and that which supplies the upper coccygeal region, which contain no pilo-motor fibres. This dividing line in the experiments in which I have specially noted the point has only varied from a position midway between the spine of the 2nd and 3rd sacral vertebræ to a position a little below the spine of the 3rd sacral vertebra. As I have indicated earlier, the corresponding line in the upper thoracic region also appears to undergo very slight variations.‡ All the

* 'Journ. of Physiol.,' vol. 12, p. 350, 1891.

† *Ibid.*, vol. 13, p. 635, 1892.

‡ Cf. also p. 555, figs. 1 and 2.

other dividing lines between the areas vary not inconsiderably in position.

The 2nd sacral ramus, as a rule, supplies the hairs of the tail just above the level of the anus and over it; the 3rd sacral ramus supplies the hairs for about an inch and a half below the level of the anus. The coccygeal ganglion gives off rami to the several coccygeal nerves, and these supply different lengths of the tail. This ganglion supplies by its rami the whole, or nearly the whole, of the tail.

The distribution of the pilo-motor post-ganglionic fibres of each spinal nerve, *i.e.*, of the fibres which run to each spinal nerve from the sympathetic system, can also be determined by stimulating the nerve inside the spinal canal. This method depends upon the spreading of the current down the nerve to its dorsal branch, in which the pilo-motor fibres run. In most cases rather strong shocks are required; in others, as in the sacral region, moderate shocks are sufficient. A similar spreading down of the current to the ventral branches of the nerves may perhaps be the explanation of the assertion that the lower lumbar nerves contain direct spinal secretory and vaso-motor fibres for the foot. When a spinal nerve sends pilo-motor fibres (pre-ganglionic fibres) to the sympathetic, as well as receiving some from it (post-ganglionic fibres), the two can readily be distinguished by injecting nicotine. This cuts out the effect of the pre-ganglionic, but not that of the post-ganglionic, fibres.

So far, I have been chiefly concerned with the description of the portion of the dorsal skin innervated by each ganglion through its grey ramus. The next question to consider is the connexion of each ganglion with the spinal cord. Like the other questions dealt with here, this must be treated somewhat broadly, since there are more or less pronounced individual variations.

In the following table I give what appear to be the ordinary connexions* in an animal in which the 4th lumbar nerve and the 6th lumbar sympathetic grey ramus contain no pilo-motor fibres. I omit the connexion of the 4th and 5th spinal nerves with the sympathetic ganglia. I insert the connexions of some spinal nerves which do not contain pilo-motor fibres. In the left-hand vertical column, the numbers refer to the spinal nerves arranged in order, beginning with the 1st thoracic. The numbers placed in a horizontal line with the number of each spinal nerve represent the sympathetic ganglia in which its fibres make connexion with nerve-cells to issue in the corresponding grey rami. S.c.g. and g.st. are used respectively for the superior cervical ganglion and the ganglion stellatum. When either of these, or the number of a ganglion, is enclosed in brackets,

* The connexion of the nerves with the uppermost and lowermost of their series of ganglia is sometimes slight only; this is especially the case as regards the connexion of the lumbar nerves with the uppermost of their series of ganglia.

it indicates that the connexion of the spinal nerve with the ganglion has been determined, not by pilo-motor, but by some other, fibres.

The facts given in the table, together with those given earlier regarding the distribution of the rami of the ganglia, show the areas of the skin which are supplied by the pilo-motor fibres issuing from the cord in the roots of each spinal nerve given in the table.

Can we from these data deduce any conclusions with regard to the distribution of the other sympathetic fibres of the spinal nerves?

I have said that the pilo-motor fibres to the skin over the vertebræ run to the periphery in the dorsal cutaneous branches of the spinal nerves. It is easily shown that the area of the skin supplied with pilo-motor fibres by the dorsal cutaneous branch of any given spinal nerve is also supplied by it with sensory fibres. And I think there is good reason for believing that the fibres of the grey ramus of a nerve, *i.e.*, the post-ganglionic sympathetic fibres of a spinal nerve, have, in the main, the same distribution in the skin as the sensory fibres of the nerve.

The chief physiological observations on the distribution of sensory fibres in the skin are those of Türck,* made on the dog, and of Sherrington,† made on the monkey. These observations give the sensory areas of both dorsal and ventral cutaneous branches. To compare with these, we have the pilo-motor nerves of a portion of the dorsal cutaneous branches, and the secretory nerves of certain ventral cutaneous branches running to the hind foot.‡ There would be no advantage in attempting here to discuss in detail the degree of coincidence in the areas of the sensory and of the visceral fibres, and chiefly because, in many cases at any rate, a given spinal nerve in any one of the animals has not an exactly corresponding spinal nerve in the other two animals. But, in my opinion, the correspondence in the areas of the sympathetic and the sensory fibres, so far as we know them, is close enough to justify the conclusion that the sensory and the post-ganglionic sympathetic fibres in any spinal nerve have, in the main, the same distribution. The chief point which may be urged against this view is that, according to Sherrington, the areas of the sensory fibres of the dorsal and upper lumbar spinal nerves largely overlap.§ An overlapping of pilo-motor fibres as great as that found by him for sensory fibres has not occurred in my experiments. On the other hand, it is to be remembered, that in my experiments—

* Türck, 'Sitzungsb. d. Wiener Akad.,' vol. 21, 1856; and 'Denkschrift. d. Wiener Akad.,' vol. 29, 1869.

† Sherrington, 'Roy. Soc. Proc.,' vol. 52, p. 333, 1893.

‡ 'Journ. of Physiol.,' vol. 12, p. 347, 1891.

§ Türck did not find overlapping, or only slight overlapping, in the nerves of the neck and trunk.

whenever the matter was tested—the pilo-motor area of a cutaneous branch was found to be supplied with sensory fibres from the same branch; that there is a certain amount of overlapping in the pilo-motor areas of successive cutaneous branches; and that the sympathetic fibres of any given kind may have a rather less or rather greater extension than the sensory fibres with which they run.

Of the distribution of sympathetic fibres to muscles we have no information, but, if the view I have given above is true, it establishes a probability that such of these fibres as may run in a given grey ramus to a nerve would have approximately the same distribution as the muscular branches of the nerve.

We have seen that at the origin of the nerves for the arm and for the leg, one, two, or three grey rami contain no pilo-motor fibres. Let us consider a simple case, say, when the 6th lumbar grey ramus has no pilo-motor fibres. Five spinal nerves, the 12th, 13th thoracic, the 1st, 2nd, 3rd lumbar, give off nerve-fibres, which leave the sympathetic by each of the grey rami of six or seven ganglia in the neighbourhood of, and including, the 6th lumbar ganglion.* Of this series of rami, the 6th lumbar is about the last supplied by the 12th thoracic, and about the first supplied by the 3rd lumbar nerve (*cf.* table above). Further, each of these spinal nerves has abundant pilo-motor fibres, and sends them to every ramus except the 6th lumbar. Why is it that the pilo-motor fibres of each nerve skip this particular ramus, skipping it wherever it comes in the series of rami supplied by the nerve? And, further, why do variations occur in different animals, so that any one or all of the grey rami of the 5th, 6th, or 7th lumbar ganglion may have no pilo-motor fibres?

The proximate explanation I take to be that the sympathetic ganglia develop in connexion with the spinal nerve-roots;† that, as is now generally believed, the number of consecutive nerve-roots passing out in a particular spinal nerve varies; that the sympathetic fibres issuing from the sympathetic ganglion to run to the nerve follow in the main the course of the nerve; and that probably the connexion of the ganglion with the cord by the white rami is a subsequent event. The following diagram represents the chief points of this explanation.

A detailed account of the facts summarised above I hope to be able to give in no long time, and then, also, I hope to deal with one or two problems of the sympathetic system which I have omitted here.

Cf. Langley, 'Journ. of Physiol.,' vol. 12, p. 347, 1891.

† According to His and others, a common mass of cells gives rise to both sympathetic and spinal ganglia.

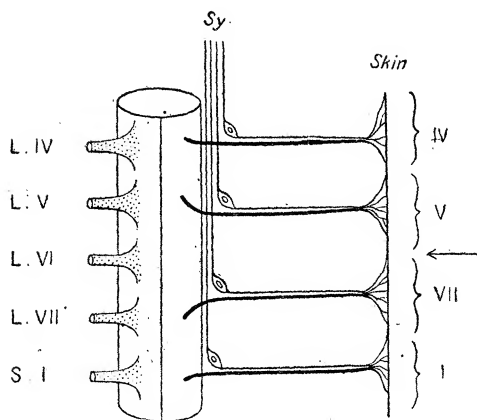


FIG. 1 is a diagram of the course of the pilo-motor and sensory fibres to the skin near the mid-dorsal line, when the 6th grey ramus contains no pilo-motor fibres. The thick lines represent the sensory spinal fibres; the thin lines accompanying them the sympathetic fibres. The arrow represents a line of skin at about the end of the sacrum.

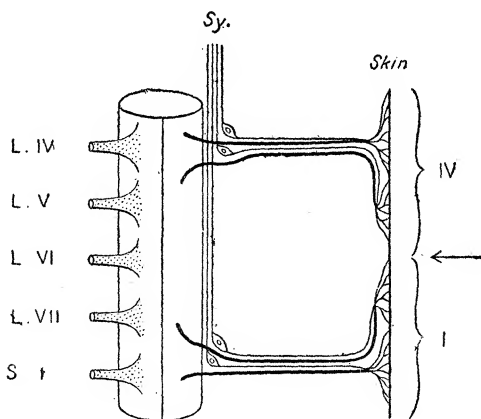


FIG. 2 is a diagram similar to that of fig. 1, but for the case when the 5th, 6th, and 7th grey rami have no pilo-motor nerves. The shifting which commonly occurs of some fibres of the 4th lumbar into the 3rd, and of some fibres of the 1st sacral into the 2nd, is here left out of account.

DESCRIPTION OF PLATE 14.

Diagram to show the connexions of—

- (a.) The spinal nerves with the ganglia of the sympathetic chain.
- (b.) The grey rami of the ganglia with the skin.

The diagram also shows the distribution of the sensory fibres of the spinal nerves with the skin of the mid-dorsal line; leaving out of account any overlapping of the areas that may occur.

The meaning of the several parts of the diagram is, for the most part, explained by the lettering.

In addition it must be noted that—

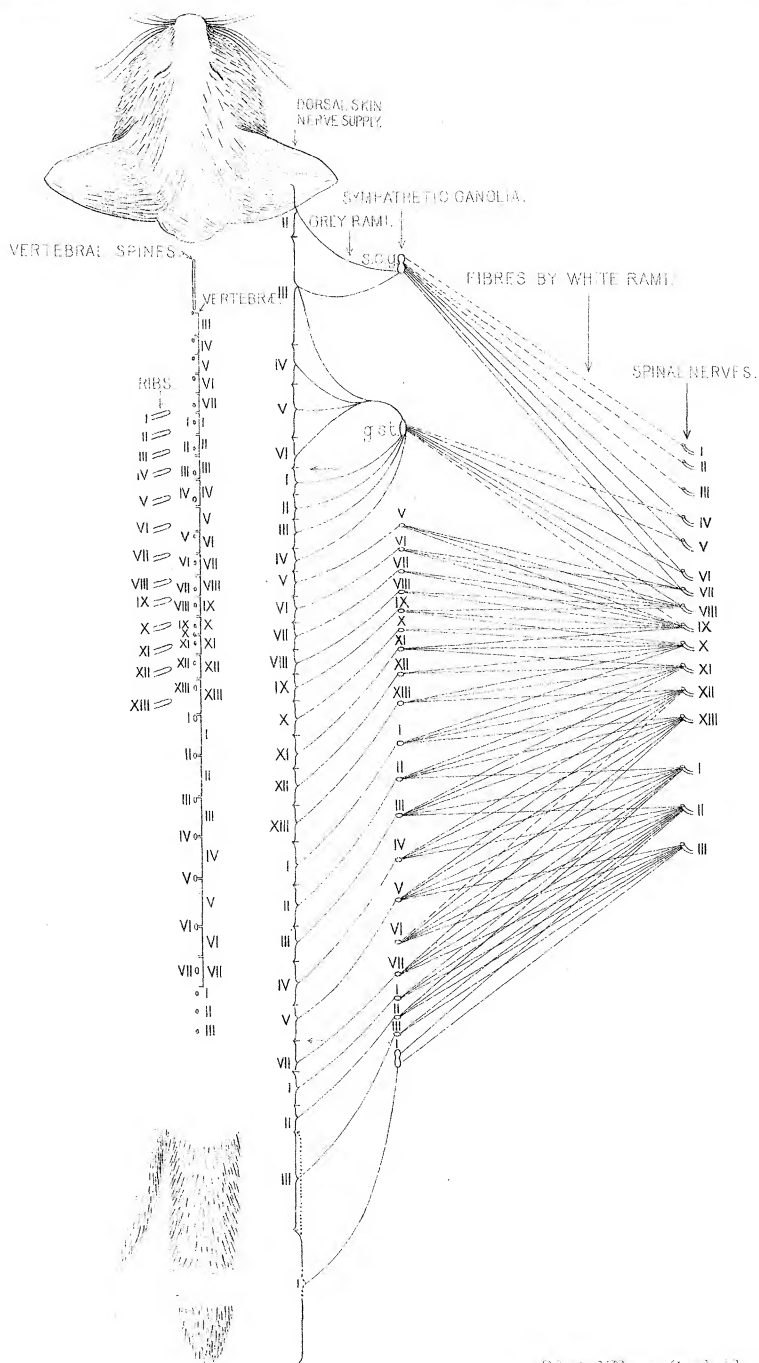
1. The broken lines indicate that the connexion shown by the line has been determined by experiments on some other than pilo-motor fibres, *e.g.*, by pupillo-dilator or by sweat-nerve fibres.
2. The connexion of the several spinal nerves with the sympathetic ganglia is not in all cases as it is represented in the diagram. There are individual variations.
3. Any one spinal nerve is connected with certain of its ganglia by a considerable number of fibres, and with others by very few. It is connected by few fibres with either the uppermost or the lowermost, or with both uppermost and lowermost, of its series of ganglia. Thus the 7th thoracic nerve sends comparatively few fibres to the superior cervical ganglion, and the 3rd lumbar nerve sends comparatively few fibres to the 5th lumbar sympathetic ganglion.
4. The distribution of the several grey rami to the skin also varies; the extent of this variation has been described in the text. In the scheme given here, the case is taken when the 7th and 8th thoracic and the 6th lumbar nerves do not run to the mid-line of the back.
5. The dotted line stretching from the upper end of the skin area of the grey ramus of the 1st coccygeal ganglion indicates that the area of the 3rd sacral grey ramus is usually supplied by fibres from the coccygeal ganglion. It will be noticed that only the base and tip of the tail are represented.

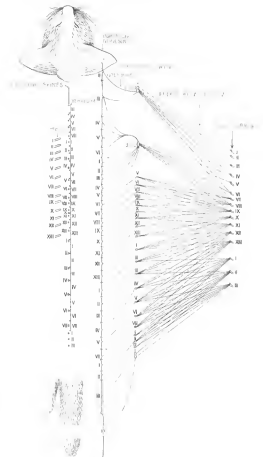
II. “Note on the Knee-jerk and the Correlation of Action of Antagonistic Muscles.” By C. S. SHERRINGTON, M.A., M.D.
Communicated by Professor M. FOSTER, Sec. R.S. Received February 1, 1893.

(From the Physiological Laboratory, St. Thomas's Hospital.)

The muscular reaction known as the knee-jerk is notoriously affected by conditions obtaining in what is often described as a reflex arc, consisting of afferent and efferent paths, and a centre situate in the lumbar portion of the spinal cord. I recently* described experiments determining more particularly than hitherto the locality of the muscular and nervous mechanism on which the jerk depends. I showed that the muscular portion of this mechanism consists mainly

* ‘Journal of Physiology,’ vol. 13, p. 666.





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1. The broken lines indicate that the connection shown by the line has been determined by experiments on some other than pilo-motor fibres, *e.g.*, by papillo-dilator or by sweat-nerve fibres.
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3. Any one spinal nerve is connected with certain of its ganglia by a considerable number of fibres, and with others by very few. It is connected by few fibres with either the uppermost or the lowermost, or with both uppermost and lowermost, of its series of ganglia. Thus the 7th thoracic nerve sends comparatively few fibres to the superior cervical ganglion, and the 3rd lumbar nerve sends comparatively few fibres to the 5th lumbar sympathetic ganglion.
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